

CLAIMS

1. An anode of an electrochemical cell, wherein said anode comprises:
an anode active layer, which anode active layer comprises:
(i) a first layer comprising lithium metal; and
(ii) a second layer of a temporary protective metal in contact with a surface of said first layer;
wherein said temporary protective metal is capable of forming an alloy with lithium metal or is capable of diffusing into lithium metal.
2. The anode of claim 1, wherein said temporary protective metal is selected from the group consisting of copper, magnesium, aluminum, silver, gold, lead, cadmium, bismuth, indium, germanium, gallium, zinc, tin, and platinum.
3. The anode of claim 1, wherein the thickness of said first layer is 2 to 100 microns.
4. The anode of claim 1, wherein the thickness of said second layer is 5 to 500 nanometers.
5. The anode of claim 1, wherein the thickness of said second layer is 20 to 200 nanometers.
6. The anode of claim 1, wherein said anode further comprises a substrate, wherein said substrate is in contact with a surface of said first layer on the side opposite to said second layer.
7. The anode of claim 6, wherein said substrate comprises a current collector.
8. The anode of claim 6, wherein said substrate is selected from the group consisting of metal foils, polymer films, metallized polymer films, electrically conductive polymer films, polymer films having an electrically conductive coating, electrically conductive

polymer films having an electrically conductive metal coating, and polymer films having conductive particles dispersed therein.

5 9. The anode of claim 1, wherein said anode further comprises a third layer, said third layer comprising a single ion conducting layer, wherein said third layer is in contact with said second layer on the side opposite to said first layer.

10 10. The anode of claim 9, wherein said single ion conducting layer comprises a glass selected from the group consisting of lithium silicates, lithium borates, lithium aluminates, lithium phosphates, lithium phosphorus oxynitrides, lithium silicosulfides, lithium germanosulfides, lithium lanthanum oxides, lithium tantalum oxides, lithium niobium oxides, lithium titanium oxides, lithium borosulfides, lithium aluminosulfides, and lithium phosphosulfides, and combinations thereof.

15 11. The anode of claim 1, wherein said anode further comprises a third layer, said third layer comprising a polymer, and wherein said third layer is in contact with said second layer on the side opposite to said first layer.

20 12. The anode of claim 11, wherein said polymer is selected from the group consisting of electrically conductive polymers, ionically conductive polymers, sulfonated polymers, and hydrocarbon polymers.

13. The anode of claim 11, wherein said polymer is a crosslinked polymer.

25 14. The anode of claim 9, wherein said anode further comprises a fourth layer, said fourth layer comprising a polymer, and wherein said fourth layer is in contact with said third layer on the side opposite to said second layer.

30 15. The anode of claim 14, wherein said polymer is selected from the group consisting of electrically conductive polymers, ionically conductive polymers, sulfonated polymers, and hydrocarbon polymers.

16. The anode of claim 14, wherein said polymer is a crosslinked polymer.
17. A method of preparing an anode of an electrochemical cell, wherein said anode is formed by the steps of:
- (a) depositing onto a substrate a first layer comprising lithium metal; and
 - (b) depositing over said first layer a second layer of a temporary protective metal; wherein said temporary protective metal is capable of forming an alloy with lithium metal or is capable of diffusing into lithium metal.
18. The method of claim 17, wherein said temporary protective metal is selected from the group consisting of copper, magnesium, aluminum, silver, gold, lead, cadmium, bismuth, indium, germanium, gallium, zinc, tin, and platinum.
19. The method of claim 17, wherein the thickness of said first layer is 2 to 100 microns.
20. The method of claim 17, wherein the thickness of said second layer is 5 to 500 nanometers.
21. The method of claim 17, wherein said substrate is selected from the group consisting of metal foils, polymer films, metallized polymer films, electrically conductive polymer films, polymer films having an electrically conductive coating, electrically conductive polymer films having an electrically conductive metal coating, and polymer films having conductive particles dispersed therein.
22. The method of claim 17, wherein said first layer is deposited in step (a) by a method selected from the group consisting of thermal evaporation, sputtering, jet vapor deposition, laser ablation, and extrusion.

23. The method of claim 17, wherein said second layer is deposited in step (b) by a method selected from the group consisting of thermal evaporation, sputtering, jet vapor deposition, and laser ablation.
- 5 24. The method of claim 17, wherein said method further comprises after step (b), a step (c) of depositing a third layer comprising a single ion conducting glass over said second layer.
- 10 25. The method of claim 24, wherein said single ion conducting glass is selected from the group consisting of lithium silicates, lithium borates, lithium aluminates, lithium phosphates, lithium phosphorus oxynitrides, lithium silicosulfides, lithium germanosulfides, lithium lanthanum oxides, lithium tantalum oxides, lithium niobium oxides, lithium titanium oxides, lithium borosulfides, lithium aluminosulfides, and lithium phosphosulfides, and combinations thereof.
- 15 26. The method of claim 24, wherein said third layer is deposited in step (c) by a method selected from the group consisting of sputtering, thermal evaporation, laser ablation, chemical vapor deposition, and jet vapor deposition.
- 20 27. The method of claim 17, wherein said method further comprises after step (b), a step (c) of depositing a third layer comprising a polymer over said second layer.
- 25 28. The method of claim 27, wherein said polymer is selected from the group consisting of electrically conductive polymers, ionically conductive polymers, sulfonated polymers, and hydrocarbon polymers.
29. The method of claim 27, wherein said polymer is a crosslinked polymer.
- 30 30. The method of claim 27, wherein said third layer is deposited by a method selected from the group consisting of thermal evaporation, sputtering, laser ablation, chemical vapor deposition, and jet vapor deposition.

31. The method of claim 27, wherein said third layer is deposited by flash evaporation.
32. The method of claim 24, wherein said method further comprises after step (c), a step
(d) of depositing a fourth layer comprising a polymer over said third layer.
33. The method of claim 32, wherein said polymer is selected from the group consisting of electrically conductive polymers, ionically conductive polymers, sulfonated polymers, and hydrocarbon polymers.
34. The method of claim 32, wherein said polymer is a crosslinked polymer.
35. The method of claim 32, wherein said fourth layer is deposited by a method selected from the group consisting of thermal evaporation, sputtering, laser ablation, chemical vapor deposition, and jet vapor deposition.
36. The method of claim 32, wherein said fourth layer is deposited by flash evaporation.
37. An electrochemical cell comprising:
(a) a cathode comprising a cathode active material;
(b) an anode; and
(c) a non-aqueous electrolyte interposed between said anode and said cathode;
wherein said anode comprises an anode active layer, which anode active layer comprises:
(i) a first layer comprising lithium metal; and
(ii) a second layer of a temporary protective metal in contact with a surface of said first layer;
wherein said temporary protective metal is capable of forming an alloy with lithium metal or is capable of diffusing into lithium metal.

38. The cell of claim 37, wherein said temporary protective metal is selected from the group consisting of copper, magnesium, aluminum, silver, gold, lead, cadmium, bismuth, indium, germanium, gallium, zinc, tin, and platinum.
- 5 39. The cell of claim 37, wherein said temporary protective metal is characterized by forming an alloy with, dissolving into, blending with, or diffusing into said lithium metal of said first layer during electrochemical cycling of said cell.
- 10 40. The cell of claim 37, wherein said temporary protective metal is characterized by forming an alloy with, dissolving into, blending with, or diffusing into said lithium metal of said first layer prior to electrochemical cycling of the cell.
41. The cell of claim 37, wherein the thickness of said first layer is 2 to 100 microns.
- 15 42. The cell of claim 37, wherein the thickness of said second layer is 5 to 500 nanometers.
- 20 43. The cell of claim 37, wherein said anode further comprises a substrate, wherein said substrate is in contact with a surface of said first layer on the side opposite to said second layer.
44. The cell of claim 43, wherein said substrate comprises a current collector.
- 25 45. The cell of claim 43, wherein said substrate is selected from the group consisting of metal foils, polymer films, metallized polymer films, electrically conductive polymer films, polymer films having an electrically conductive coating, electrically conductive polymer films having an electrically conductive metal coating, and polymer films having conductive particles dispersed therein.

46. The cell of claim 37, wherein said anode further comprises a third layer, said third layer comprising a single ion conducting layer, wherein said third layer is in contact with said second layer on the side opposite to said first layer.
- 5 47. The cell of claim 46 wherein said single ion conducting layer of said third layer comprises a glass selected from the group consisting of lithium silicates, lithium borates, lithium aluminates, lithium phosphates, lithium phosphorus oxynitrides, lithium silicosulfides, lithium germanosulfides, lithium lanthanum oxides, lithium tantalum oxides, lithium niobium oxides, lithium titanium oxides, lithium borosulfides, lithium aluminosulfides, and lithium phosphosulfides, and combinations thereof.
- 10 48. The cell of claim 37, wherein said anode further comprises a third layer, said third layer comprising a polymer, and wherein said third layer is in contact with said second layer on the side opposite to said first layer.
- 15 49. The cell of claim 48, wherein said polymer is selected from the group consisting of electrically conductive polymers, ionically conductive polymers, sulfonated polymers, and hydrocarbon polymers.
- 20 50. The cell of claim 48, wherein said polymer is a crosslinked polymer.
51. The cell of claim 46, wherein said anode further comprises a fourth layer, said fourth layer comprising a polymer, and wherein said fourth layer is in contact with said third layer on the side opposite to said second layer.
- 25 52. The cell of claim 51, wherein said polymer is selected from the group consisting of electrically conductive polymers, ionically conductive polymers, sulfonated polymers, and hydrocarbon polymers.
- 30 53. The cell of claim 51, wherein said polymer is a crosslinked polymer.

54. The cell of claim 37, wherein said electrolyte is selected from the group consisting of liquid electrolytes, solid polymer electrolytes and gel polymer electrolytes.
55. The cell of claim 37, wherein said electrolyte comprises a separator selected from the group consisting of polyolefin separators and microporous xerogel layer separators.
56. The cell of claim 37, wherein said cathode active material comprises one or more materials selected from the group consisting of electroactive metal chalcogenides, electroactive conductive polymers, and electroactive sulfur-containing materials, and combinations thereof.
57. The cell of claim 37, wherein said cathode active material comprises elemental sulfur.
58. The cell of claim 37, wherein said cathode active material comprises an electroactive sulfur-containing organic polymer, wherein said sulfur-containing organic polymer, in its oxidized state, comprises one or more polysulfide moieties, $-S_m^-$, where m is an integer equal to or greater than 3.
59. The cell of claim 37, wherein said cathode active material comprises an electroactive sulfur-containing organic polymer, wherein said sulfur-containing organic polymer, in its oxidized state, comprises one or more polysulfide moieties, $-S_m^-$, where m is an integer equal to or greater than 3.
60. The cell of claim 37, wherein said cathode active material comprises an electroactive sulfur-containing organic polymer, wherein said sulfur-containing organic polymer, in its oxidized state, comprises one or more polysulfide moieties, S_m^{2-} , where m is an integer equal to or greater than 3.
61. The cell of claim 37, wherein said cell is a secondary cell.
62. The cell of claim 37, wherein said cell is a primary cell.

63. A method for making an electrochemical cell, said method comprising the steps of:
- (a) providing a cathode comprising a cathode active material;
 - (b) providing an anode, wherein said anode comprises an anode active layer, which anode active layer comprises:
 - (i) a first layer comprising lithium; and
 - (ii) a second layer of a temporary protective metal in contact with a first surface of said first layer; and
 - (c) providing a non-aqueous electrolyte, wherein said electrolyte is interposed between said anode and said cathode;
- wherein said temporary protective metal is capable of forming an alloy with lithium metal or is capable of diffusing into lithium metal.
64. The method of claim 63, wherein said temporary protective metal is selected from the group consisting of copper, magnesium, aluminum, silver, gold, lead, cadmium, bismuth, indium, germanium, gallium, zinc, tin, and platinum
65. The method of claim 63, wherein said temporary protective metal forms an alloy with or diffuses into said lithium metal of said first layer during electrochemical cycling of said cell.
66. The method of claim 63, wherein said temporary protective metal forms an alloy with or diffuses into said lithium metal of said first layer prior to electrochemical cycling of said cell.
67. The method of claim 63, wherein said anode further comprises a substrate, wherein said substrate is in contact with a surface of said first layer on the side opposite to said second layer.
68. The method of claim 67, wherein said first layer is deposited onto said substrate by a method selected from the group consisting of thermal evaporation, sputtering, jet vapor deposition, laser ablation, and extrusion.

69. The method of claim 63, wherein said second layer is deposited onto the surface of said first layer by a method selected from the group consisting of thermal evaporation, sputtering, jet vapor deposition, and laser ablation.

5 70. The method of claim 63, wherein said anode further comprises a third layer, said third layer comprising a single ion conducting material, wherein said third layer is in contact with said second layer on the side opposite to said first layer.

10 71. The method of claim 70, wherein said single ion conducting material comprises a glass selected from the group consisting of lithium silicates, lithium borates, lithium aluminates, lithium phosphates, lithium phosphorus oxynitrides, lithium silicosulfides, lithium germanosulfides, lithium lanthanum oxides, lithium tantalum oxides, lithium niobium oxides, lithium titanium oxides, lithium borosulfides, lithium aluminosulfides, and lithium phosphosulfides, and combinations thereof.

15 72. The method of claim 63, wherein said anode further comprises a third layer, said third layer comprising a polymer, wherein said third layer is in contact with said second layer on the side opposite to said first layer.

20 73. The method of claim 72, wherein said polymer is selected from the group consisting of electrically conductive polymers, ionically conductive polymers, sulfonated polymers, and hydrocarbon polymers.

25 74. The method of claim 72, wherein said polymer is a crosslinked polymer.

75. The method of claim 70, wherein said anode further comprises a fourth layer, said fourth layer comprising a polymer, wherein said fourth layer is in contact with said third layer on the side opposite to said second layer.

76. The method of claim 75, wherein said polymer is selected from the group consisting of electrically conductive polymers, ionically conductive polymers, sulfonated polymers, and hydrocarbon polymers.

5 77. The method of claim 75, wherein said polymer is a crosslinked polymer.

78. The method of claim 70, wherein said third layer is deposited on said second layer by a method selected from the group consisting of sputtering, electron beam evaporation, vacuum thermal evaporation, laser ablation, chemical vapor deposition, thermal evaporation, plasma enhanced chemical vacuum deposition, laser enhanced chemical vapor deposition, and jet vapor deposition.

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79. The method of claim 72, wherein said third layer is deposited on said second layer by a method selected from the group consisting of electron beam evaporation, vacuum thermal evaporation, laser ablation, chemical vapor deposition, thermal evaporation, plasma assisted chemical vacuum deposition, laser enhanced chemical vapor deposition, and jet vapor deposition.

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80. The method of claim 75, wherein said fourth layer is deposited on said third layer by a method selected from the group consisting of electron beam evaporation, vacuum thermal evaporation, laser ablation, chemical vapor deposition, thermal evaporation, plasma assisted chemical vacuum deposition, laser enhanced chemical vapor deposition, and jet vapor deposition.

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81. The method of claim 63, wherein said electrolyte element is selected from the group consisting of liquid electrolyte elements, solid polymer electrolyte elements and gel-polymer electrolyte elements.

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82. The method of claim 63, wherein said cathode active material comprises one or more materials selected from the group consisting electroactive metal chalcogenides,

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The method of claim 63, wherein said second layer is deposited on said first layer by a method selected from the group consisting of thermal evaporation, sputtering, jet vapor deposition, laser ablation, and extrusion.

Variable	Mean	Standard Deviation	Minimum	Maximum
Age	34.5	10.2	21	55
Gender	0.48	0.50	0	1
Marital Status	0.65	0.48	0	1
Education	12.5	1.8	9	16
Income	25.5	15.2	10	60
Health	0.72	0.45	0	1
Religion	0.35	0.48	0	1
Occupation	0.45	0.52	0	1
Political Party	0.32	0.46	0	1
Home Ownership	0.68	0.47	0	1
Auto Ownership	0.75	0.43	0	1
Life Satisfaction	0.62	0.49	0	1
Health Satisfaction	0.58	0.49	0	1
Income Satisfaction	0.55	0.50	0	1
Home Satisfaction	0.60	0.48	0	1
Auto Satisfaction	0.65	0.47	0	1
Life Satisfaction	0.62	0.49	0	1
Health Satisfaction	0.58	0.49	0	1
Income Satisfaction	0.55	0.50	0	1
Home Satisfaction	0.60	0.48	0	1
Auto Satisfaction	0.65	0.47	0	1